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13. ABSTRACT (Maximum 200 Words) In support of the US Army Research Laboratory, Human Research and Engineering Directorate, HSIAC, the Human Systems Information Analysis Center, conducted an extensive search of scientific literature to identify state-of-the-art research relevant to auditory workload assessment. This volume (II) contains the literature search results from selected non-copyrighted databases.			
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NOTICE

This report contains three volumes. Volume I is the final report on auditory workload assessment measures. Volume II, this volume, contains pertinent non-copyrighted citations extracted from government databases, and Volume III contains pertinent copyrighted citations extracted from commercial databases. A table of contents for the three-volume set may be found in Volume I.

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1. NON-COPYRIGHTED LITERATURE SEARCH INTRODUCTION

1.1 INTRODUCTION

In support of the US Army Research Laboratory (ARL), Human Research and Engineering Directorate, HSIAC, the Human Systems Information Analysis Center, conducted an extensive search of scientific literature to identify state-of-the-art research relevant to job-specific body composition standards. This volume (II) contains the literature search results from selected non-copyrighted databases.

1.2 LITERATURE SEARCH STRATEGY

1.2.1 Background

Human Systems IAC was asked to prepare a *Review & Analysis* on workload measures or scales that can be used to assess the workload demands associated with auditory processing. This effort stems from ARL studies showing that 3-D audio displays allow operators to process a significantly greater number of target messages in a shorter time than with traditional monaural displays. However, the traditional measures of workload (NASA TLX [Task Load Index] and SWAT [Subjective Workload Assessment Technique]) do not indicate any difference in the level of workload between the two displays. This information suggests that these results are due to a lack of sensitivity in the scales used. Therefore, a suitable and valid measure of auditory workload must be identified and employed. The identification of this measure is the primary goal of this literature search.

It should be noted that ARL was not aware of any measurement that could assess workload demands associated with auditory processing. Therefore, special attention was given to prevent Human Systems IAC from missing any major sources of information. However, if no auditory workload scale was available, Human Systems IAC was responsible for providing recommendations for the development of a research plan that would result in a methodology that was capable of detecting auditory processing demands.

1.2.2 Search Terms

See table of terms in Volume I.

1.2.3 Key Authors

David G. Payne

Christopher D. Wickens

F. Thomas Eggemeier

Mark Erickson

Richard L. McKinley

Leslie J. Peters (to see her references)

2. DATABASE SEARCHED

The results of the DTIC DROLS (Defense RDT/R On-Line System) database literature search are presented in this volume.

3. ORDERING DOCUMENTS

Most of the documents identified in this search can be obtained through local resources, such as city, university, or company libraries or through inter-library loan programs sponsored by these libraries. However, some of these documents may be available only through special organizations, such as the Defense Technical Information Center (DTIC), National Technical Information Service (NTIS), or other commercial document vendors.

3.1 DEFENSE TECHNICAL INFORMATION CENTER (DTIC)

DTIC is the central repository for documents resulting from research supported by the Department of Defense (DOD). DTIC maintains several databases, including Technical Report (TR) database, Technical Effort and Management System (TEAMS) Database, and Independent Research and Development (IR&D) Databases.

Documents from the DTIC TR database (including documents from the DTIC CD-ROM) are identified by an accession number that begins with "AD," such as AD-A123 456. Most of these documents are available through DTIC. Some of the documents may not be available through DTIC; however, the citations for these documents contain the necessary document acquisition information.

To order DTIC documents, organizations must have a deposit account established with the National Technical Information Service (NTIS, see below), against which document ordering fees will be charged. Call DTIC if you do not have information on establishing a deposit account with NTIS. When ordering documents from DTIC, please cite your DTIC User Code.

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<http://www.fedworld.gov/ntis/ntishome.html>

3.3 HUMAN SYSTEMS INFORMATION ANALYSIS CENTER (HSIAC)

We recommend that you discuss potential document orders with your in-house or local technical information specialist. He or she will know the most appropriate method to place orders for documents identified in this report. If questions do arise, please feel free to contact the Human Systems Information Analysis Center (HSIAC) at the address below.

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<http://iac.dtic.mil/hsiac>

4. NON-COPYRIGHTED LITERATURE SEARCH

AMELL, J. R. & CRAWFORD, E. E. (1987). *A COMPARISON OF TWO CHORD KEYBOARD CODING SYSTEMS FOR ALPHANUMERIC DATA ENTRY*. WRIGHT-PATTERSON AFB, OH: AERONAUTICAL SYSTEMS DIVISION. (DTIC NO. ADA189230)

Abstract: Chord keyboards are alphanumeric data entry devices that generally have fewer keys than a standard typewriter keyboard. Characters are produced by pressing either a single key or several keys simultaneously. Two coding systems, both using one-handed operation, were implemented on a commercially available chord keyboard, the Microwriter. The coding system resident on the Microwriter was compared to the coding system developed by Sidorsky (1974), known as the Alpha-dot system. Measures of time to learn, time to reach a 35 character per minute criterion entry rate, text entry speed and accuracy, and cognitive workload were collected from two groups of ten subjects. Cognitive workload was measured using two auditory tasks in a secondary task paradigm. The results of initial code learning indicated that the two groups did not differ in the amount of time needed to reach a 95 percent accuracy criterion. The Alpha-dot group was, however, quicker in reaching the 35 character per minute speed criterion. Text entry was measured three times during the experiment. The first test, immediately after initial learning of the codes, indicated that the Alpha-dot group was typing at a faster rate, with no difference in errors. The second and third tests showed no differences in speed or accuracy. Based on secondary task performance, the Alpha-dot chord system appeared to require less cognitive workload than the.

AUDIO EFFECTIVENESS IN AVIATION (L'EFFICACITE DES COMMUNICATIONS VOCALES EN AERONAUTIQUE) (1997). NEUILLY-SUR-SEINE, FRANCE: ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT. (DTIC NO. ADA327142)

Abstract: The Aerospace Medical Panel of the Advisory Group for Aerospace Research and Development (AGARD) held a Symposium entitled 'Audio Effectiveness in Aviation', in Copenhagen, Denmark, 7-11 October 1996. It was held in order to address concerns that, while effective voice communications and aural signals are important in military and civil aviation, their implementations are often less than satisfactory in modern aircraft. Factors that influence this are: (a) in many cases audio communications systems in aircraft are based on design concepts that are dated and do not take advantage of recent advances in the area; (b) the noise environments in which the aviator performs often cause acoustic interference with attempts to communicate by means of auditory channels; (c) prolonged exposure to those same noise environments causes temporary and even permanent hearing impairment to the operator; (d) audio signals used as warnings, cautions and advisories are non-standardized and not optimally designed; (e) often audio displays are designed without adequate consideration being given to how they will be integrated into the aircraft systems within which they.

BLAZIE, D. B. & CRANMER, T. V. (1976). *AN AUDIO-TACTILE DISPLAY*. ABERDEEN PROVING GROUND, MD: HUMAN ENGINEERING LAB. (DTIC NO. ADA035419)

Abstract: Several devices have been developed enabling the blind to adapt to digital and visual displays. Most require extensive training and are relatively expensive. The audio-tactile display described in this paper requires very little training and promises to be inexpensive. Prototypes of the display have been developed for a digital stopwatch, a digital clock, and several electronic calculators. Because the device makes use of electrical impulses to communicate with the blind, it also has numerous potential capabilities as a research tool. The device is based on a panel containing columns of braille digits that are made active through a logic circuit interfacing the braille display with a calculator or other device. The subject scans the braille columns and discoversthe digits active in each column when a tone is produced simultaneously with the finger contacting the braille digit.

BOUCEK, G. S., ORR, H. A., WILLIAMS, R. D., MONTECALVO, A. J., & REDDEN, M. C. (1996). *INTEGRATED MISSION PRECISION ATTACK COCKPIT TECHNOLOGY (IMPACT). PHASE 2. CUEING BENEFITS OF LARGE TACTICAL SITUATION DISPLAYS, HELMET-MOUNTED DISPLAYS, AND DIRECTIONAL AUDIO*. DAYTON, OH: VEDA INC. (DTIC NO. ADA309072)

Abstract: The Wright Laboratory has initiated a program called the Integrated Mission/Precision Attack Cockpit Technology (IMPACT) program, whose purpose is to determine cockpit and Pilot-Vehicle Interface (PVI) requirements for a single-seat, multi-role fighter aircraft performing at night and in adverse weather. A structured systems engineering process is being utilized to focus on the conceptual phase of cockpit development. In support of this, Veda has employed a building block approach consisting of a literature review, design work, mission/human factors analysis, and pilot-in-the-loop simulation. The focus of this evaluation was on the integration of Helmet-Mounted Displays (HMD), Large Tactical Situation Displays (TSD), and Directional Audio to aid the pilot in threat and target acquisition (functions that are currently supported by a second crewmember). In order to understand the effects of integrating such technologies in a fighter aircraft cockpit, the F-15E weapon system was used as a baseline for comparison. A portion of a full mission simulation was developed and executed, and required a single pilot to fly an air interdiction mission using both the baseline cockpit and the advanced IMPACT cockpit. Results indicated a significant improvement in threat acquisition time and threat acquisition success rate, and a slight improvement in target acquisition, with the IMPACT cockpit.

BOURBON, T. (1967). *STUDY OF MULTI-FREQUENCY AUDITORY AND VISUAL DISPLAYS FOR SONARS HAVING MULTIPLE FIXED BEAMS*. AUSTIN, TX: TRACOR, INC. (DTIC NO. AD0807767)

Abstract: Through personal communication, R. S. Gales (USNEL) has pointed out that the British are using a multiple frequency audio display on one of their sonars with some success. The possibility suggests itself that such a system might be used to support visual displays in sonars having multiple fixed beams. The present study was undertaken to determine the detection capabilities of the operator with respect to the simultaneous presentation of multi-frequency auditory and visual signals in combination with temporal uncertainty. Previous studies of detectability with frequency uncertainty were not concerned with the effects of temporal uncertainty or of simultaneous presentation in two sensory modalities. Studies of detectability with simultaneous presentation in two sensory modalities were not concerned with the effects of temporal and frequency uncertainty. The present study consisted of determining the signal levels required to maintain the same level of detectability for auditory and for visual signals when the time interval between successive signals varied randomly from 5 to 25 sec. The signal, when it did occur, could be one of from 1 to 7 possible frequencies, the number possible being fixed for any given observation session. The auditory and visual signals were then presented simultaneously and the resulting detectability observed.

BRAITHWAITE, M. G., DURNFORD, S. J., DEROCHE, S. L., ALVAREZ, E. A., & JONES, H. D. (1997). *FLIGHT SIMULATOR EVALUATION OF A NOVEL DISPLAY TO MINIMIZE THE RISKS OF SPATIAL DISORIENTATION*. FORT RUCKER, AL: ARMY AEROMEDICAL RESEARCH LAB. (DTIC NO. ADA322607)

Abstract: A novel instrument display designed to reduce cognitive workload and improve accuracy of flight and recovery from a disorienting episode was tested against flight with standard instruments in a UH-60 dynamic helicopter simulator. Sixteen non-UH-60 rated pilots flew a standard instrument profile and recovered from a series of unusual attitudes both with and without a secondary task. Results from all aspects of the assessment proved the benefits of the new display. Not only was there evidence of enhanced flight control, but also an improved performance on a secondary task (auditory tone identification), and reduced control input errors. Evidence from analysis of the secondary task scores showed that cognitive workload was reduced when using the novel display compared to the standard instruments. The display should be further developed to make it possible to utilize it in a head-up display or other night vision device. It should also be developed to include the capability to display hover information and an instrument landing system. Future testing should be carried out in real flight.

BRAVO, A. S., FRANZ, C. M., & VANDERVLIET, S. D. (1995). *VIDEO AND AUDIO DATA ACQUISITION AND DISPLAY SYSTEM AND AUDIO COMMUNICATION SYSTEMS FOR ELECTRO-OPTICAL SYSTEM EVALUATION*. SILVER SPRING, MD: NAVAL SURFACE WARFARE CENTER. (DTIC NO. ADB202653)

Abstract: The Electro-optical Systems Evaluation Program was conducted in July 1993 for the purpose of evaluating the performances of four electro-optical (E-O) tracking systems to determine their suitability for a variety of Navy shipboard applications. As a part of this evaluation, a Video and Audio Data Acquisition (VADAD) System was designed to record, distribute, annotate, and display video signals produced by each of the E-O systems under test. In addition, the VADAD System was designed to distribute and record audio communications and IRIG-B time code. A technical description of the VADAD System is provided herein.

CALHOUN, G. L. & JANSON, W. (1991). *EYE LINE-OF-SIGHT CONTROL COMPARED TO MANUAL SELECTION OF DISCRETE SWITCHES*. DAYTON, OH: LOGICON TECHNICAL SERVICES, INC. (DTIC NO. ADA273019)

Abstract: Eye-controlled switching has been proposed as a biocybernetic control approach which may increase system effectiveness while reducing pilot workload. In this experiment, six subjects selected discrete switches on the front panel of a cockpit simulator while manually tracking a target. In two eye-controlled methods, the subjects directed their gaze at the switch indicated by an auditory cue and then made a consent input (either a manual response or a verbal response). In a conventional manual condition, subjects selected the switches with their left hand. The analysis of mean switching time suggests that eye control is a feasible alternative when hands-off control is desired. Tracking performance was found to differ significantly among switching conditions, indicating the importance of quantifying the efficiency of candidate control methods in visual workload environments analogous to that of the application environment.

CARDOSI, K. & MURPHY, E. D. (1995). *HUMAN FACTORS FOR THE DESIGN AND EVALUATION OF AIR TRAFFIC CONTROL SYSTEMS*. CAMBRIDGE, MA: JOHN A VOLPE NATIONAL TRANSPORTATION SYSTEMS CENTER. (DTIC NO. ADA286863)

Abstract: This document presents human factors issues that should be considered in the design and evaluation of air traffic control (ATC) systems and subsystems. The checklist is a companion document to Human Factors in the Design and Evaluation of Air Traffic Control

Systems. The goal of this checklist is to point air traffic controllers and other operations specialists to questions that they may wish to consider in their evaluation of new systems or subsystems, or a new component of an existing system. Some checklist items may be used as a rough filter for known design flaws; others are more appropriate for group discussion. The numbers in parenthesis at the end of each checklist item refer to the section in Human Factors in the Design and Evaluation of Air Traffic Control Systems that discusses the issue. This mapping allows the checklist user to learn about the basis for the item, why it is important, and the implications of compromise. Checklist items marked with an 'E' indicate items that must be assessed with equipment and/or by referring to the specifications documentation.

COHEN, D. WHERRY, R. J., JR., & GLENN, F. (1993). *A CRITICAL ANALYSIS OF WORKLOAD PREDICTIONS GENERATED BY MULTIPLE RESOURCE THEORY DURING EARLY CREWSTATION DESIGN*. WARMINSTER, PA: NAVAL AIR WARFARE CENTER AIRCRAFT DIV AIR VEHICLE AND CREW SYSTEMS TECHNOLOGY DEPT. (DTIC NO. ADA274804)

Abstract: Subjective workload ratings based on multiple resource theory were independently collected from two highly experienced pilots for 225 different tasks of an anticipated mission for a future advanced strike aircraft. Factor analysis of their responses suggest that while such ratings could have little actual validity in and even high inter-rater reliabilities, the ratings have high face validity and even high inter-rater reliabilities, the ratings could have little actual validity in terms of efforts required to utilize the seven postulated resource channels (visual or auditory input, spatial, verbal, or analytical cognition, and manual or speech output). Ratings of efforts required for various postulated cognitive resource channels were particularly suspect. Four independent factors were identified for each pilot which accounted for virtually all of the intercorrelations among the seven resource channels. Three factors (visual-spatial, verbal communications, and manual and speech output) were identical for both pilots and accounted for most of their explainable variance.

CORKER, K. M., CRAMER, N. L., HENRY, E. H., & SMOOT, D. E. (1990). *METHODOLOGY FOR EVALUATION OF AUTOMATION IMPACTS ON TACTICAL COMMAND AND CONTROL (C2) SYSTEMS*. CAMBRIDGE, MA: BOLT BERANEK AND NEWMAN, INC. (DTIC NO. ADA245573)

Abstract: This effort concerns the research and development of a prototype methodology to assess the impacts of automation on Air Force tactical Command and Control (C2) systems and operators. The approach uses an object-oriented software paradigm to encode of human operator performance, on screen C2 interfaces, and scenarios. Specifically, the prototype methodology provides an environment whereby the analyst can manipulate tactical scenarios and equipment characteristics as they relate to the Control Reporting Center and its automation initiatives. These configurations can then be exercised in conjunction with the human performance models via time-event simulation. Thus, human performance data and operational results are available for examination and, hence, potentially useful as guidance for automation initiatives. This final report describes the introduction of a human-in-loop capability. The methodology originally contained an open-loop emulation of five key C2 operators and models of their visual, auditory, cognitive, and psychomotor (VACP) respectively. Through voice input and output, as well as touch-panel input, an actual operator can now interact with the emulated operators in a real-time, closed-loop capacity. Thus, human performance data collection and validation of the VACP models are viable.

CORKER, K. M., CRAMER, N., & HENRY, E. (1990). *METHODOLOGY FOR EVALUATION OF AUTOMATION IMPACTS ON TACTICAL COMMAND AND CONTROL (C2) SYSTEMS*:

IMPLEMENTATION. CAMBRIDGE, MA: BBN SYSTEMS AND TECHNOLOGIES CORP. (DTIC NO. ADA223839)

Abstract: This project is developing a methodology for evaluating the impact of automation on tactical command and control (C2) operators. The focus is on prototypic man/machine systems and their automation alternatives in a simulated system context. Although the methodology has initially been developed to simulate operators using a soon-to-be-fielded tactical ground control radar system, the methods, models, and software tools are generally applicable for use in other cases. A modular architecture promotes this feature, as well as experimentation with different modeling approaches. The methodology, hosted on a mini-computer workstation, is composed of three major components; human performance models, which consist of cognitive, visual, auditory, and psychomotor components; rapid prototyping tools for prototyping of man/machine systems and interfaces; and utilities for specifying a scenario with which to exercise the system and human models. The designer/analyst can modify the configuration and function of the system or the assumptions underlying human performance through screen-based utilities. A simulation of a scenario produces human performance data as if the scenario were executed by real operators. The workstation provides a timeline of events, activity profiles, and subjective workload estimates.

CROWLEY, J. S., CALDWELL, J. A., CALDWELL, J. L., EARHEART, S., & TIBBETTS, C. (1997). *AN INEXPENSIVE PORTABLE DESKTOP FLIGHT SIMULATION TASK. FORT RUCKER, AL: ARMY AEROMEDICAL RESEARCH LAB. (DTIC NO. ADA327274)*

Abstract: A modified recreational flight simulation was tested as part of two recent studies examining the effects of Dexedrine on sleep deprived aviators. Software and controls for this task cost under \$250. Six male and five female UH-60 pilots were sleep deprived for 40 hours twice in a double-blind repeated measures study comparing 10 mg Dexedrine (x3 doses) to placebo. Every 4 hours, subjects flew the profile and were scored on their speed and accuracy of flying a simulated light fixed-wing aircraft through 22 gates under varying wind conditions. In the males, a drug x session interaction ($p=0.0361$) was due to variability with placebo but not Dexedrine. An auditory reaction time secondary task was added to the female pilots' workload resulting in a consistent (but not statistically significant) trend toward worse performance in the placebo condition. The drawbacks of this crude measure of flight performance must be weighed against the costs and feasibility of high fidelity flight simulation or in-flight research. Detailed task design specifications are provided.

DEUTSCH, S. E., MACMILLAN, J., CAMER, N. L., & CHOPRA, S. (1997). *OPERABILITY MODEL ARCHITECTURE DEMONSTRATION FINAL REPORT. CAMBRIDGE, MA: BOLT BERANEK AND NEWMAN, INC. (DTIC NO. ADA326210)*

Abstract: The Operator Model Architecture (OMAR) is an integrated suite of software tools to support the construction of Human Performance Process (HPP) models. This report documents the use of OMAR to create and test HPP models for Air Traffic Control (ATC) and research in anthropometric human modeling. In addition, this report documents the development of new model analysis tools.

DOLL, T. J., FOLDS, D. J., & LEIKER, L. A. (1984). *AUDITORY INFORMATION SYSTEMS IN MILITARY AIRCRAFT: CURRENT CONFIGURATIONS VERSUS THE STATE OF THE ART*. ATLANTA, GA: GEORGIA INSTITUTE OF TECH SYSTEMS ENGINEERING LAB. (DTIC NO. ADA145469)

Abstract: The complete ensembles of auditory signals in selected USAF aircraft (the F-4D, F-15, two models of the F-16, the C-5, and the C-141) are described and evaluated. Human factors research related to the design of speech and non-speech and non-speech auditory signals is reviewed and the fundamentals of speech synthesis technology are described. Major findings are: that auditory signals are not well standardized among the aircraft, even between those with similar combat roles that a relatively large number of non-speech auditory signals are used, which may make it difficult for the aircrew to recall the meanings of all the signals; that some non-speech signals are sufficiently similar that they may be confused, particularly in high workload and stressful conditions; and that the criticality of the warnings is not reliably indicated by any characteristic of the signals. Five problem areas requiring further research are discussed: reduction of signal loudness, annoyance, and disruption of other functions; enhancement of the distinctiveness and masking resistance of non-speech signals; effects of concurrent warning signals on aircrew performance in critical operational contexts; additional uses of auditory information in order to relieve visual workload; the need for guidelines for deciding which information should be provided aurally, which should be speech versus non-speech, and for designing speech messages; and optimization of synthesized speech for cockpit applications, including its attention-getting capability, distinctiveness, intelligibility, and ease of comprehension.

DONCHIN, E. & WICKENS, C. (1981). *THE EVENT RELATED BRAIN POTENTIAL AS AN INDEX OF INFORMATION PROCESSING, COGNITIVE ACTIVITY, AND SKILL ACQUISITION: A PROGRAM OF BASIC RESEARCH*. CHAMPAIGN, IL: ILLINOIS UNIVERSITY PSYCHOPHYSIOLOGY LAB. (DTIC NO. ADA111057)

Abstract: This report describes experiments and developments related to six basic categories of research on the event-related brain potential, performance, and cognition: (1) Tracking, attention, and workload; (2) automation, skill learning, memory, and the 'depth' of information processing; (3) individual differences; (4) mental chronometry; (5) other components of the ERP than P300; and (6) methodologies and analytical techniques.

DONCHIN, E. & WICKENS, C. D. (1980). *APPLICATIONS OF EVENT-RELATED BRAIN POTENTIALS IN HUMAN ENGINEERING*. CHAMPAIGN, IL: ILLINOIS UNIVERSITY PSYCHOPHYSIOLOGY LAB. (DTIC NO. ADA097007)

Abstract: This report describes research partially or entirely conducted during the first year of the contract period. It describes experiments related to four basic categories of human performance research: attention (including both attention allocation and workload), subjective probability and expectancy, processing latency, and control movement. A series of appendices describes those portions of the research that have been completed.

DONCHIN, E., WICKENS, C., & COLES, M. G. H. (1982). *THE EVENT RELATED BRAIN POTENTIAL AS AN INDEX OF INFORMATION PROCESSING, COGNITIVE ACTIVITY, AND SKILL ACQUISITION: A PROGRAM OF BASIC RESEARCH*. CHAMPAIGN, IL: ILLINOIS UNIVERSITY PSYCHOPHYSIOLOGY LAB. (DTIC NO. ADA125699)

Abstract: The materials assembled in this report represent work conducted with AFOSR support at the Cognitive Psychophysiology Laboratory during the reporting period. Articles discussed in this report follow: Cognitive Psychophysiology and Preparatory Processes - A Case Study; A

New Method for Off-Line Removal of Ocular Artifact; The Performance of Concurrent Tasks: A Psychophysiological Analysis of the Reciprocity of Information Processing Resources; P300 and Memory: Individual Differences in the von Restorff Effect; N200 Amplitude as a Function of Degree of Mismatch in a Word Categorization Paradigm; P300 Latency and Reaction Time from a Visual Search Task with Varying Levels of Noise and S-R Compatibility; Electrophysiology of Absolute Pitch; Information Extraction and P300 Amplitude; Operator Workload as a Function of the System State - An Analysis Based upon the Event-Related Brain Potential; Pseudo-Quicken: A New Display Technique for the Control of Higher Order Systems; and An Investigation of Redundant.

ELIAS, B. (1995). *THE COORDINATION OF DYNAMIC VISUAL AND AUDITORY SPATIAL PERCEPTS AND RESPONSIVE MOTOR ACTIONS: A REVIEW AND INTEGRATION OF CURRENT THEORY AND RESEARCH*. BROOKS AFB, TX: ARMSTRONG LAB OCCUPATIONAL AND ENVIRONMENTAL HEALTH DIRECTORATE. (DTIC NO. ADA302989)

Abstract: This review is intended to serve as an integration of current research and thought regarding visual and auditory spatial perception in an effort to consolidate diverse theoretical viewpoints and empirical findings. The aim of this technical report is to derive a unified account of bimodal spatial perception and responsive motor actions. The model of bimodal information processing developed in this report will serve as a basis for defining issues of concern regarding the implementation of bimodal spatial displays that require the individual to integrate dynamic spatial information acquired both aurally and visually. This model draws upon theory and research from ecological and information processing perspectives of auditory and visual perception. The model posits that information regarding the spatial layout and spatial dynamics of the environment is incrementally accrued through multiple modalities including vision and audition to form a common functional representation of spatio-temporal parameters. The key parameters of dynamic spatial position and motion conveyed in this functional representation are subsequently utilized to formulate plans and programs for responsive actions. Currently, a research program examining the process of cross-modal integration of dynamic auditory and visual information is underway. The findings of this research will have important implications for the implementation of 3-D auditory display technology for conveying dynamic spatial information in high visual workload environments.

ERLICK, D. & HUNT, D. P. (1957). *EVALUATING AUDIO WARNING DISPLAYS FOR WEAPON SYSTEMS*. WRIGHT-PATTERSON AFB, OH: AEROSPACE MEDICAL RESEARCH LABS. (DTIC NO. AD0118189)

GIBIAN, G. & PEPE, K. (1997). *ADVANCED AUDIO AND VIRTUAL HUMAN SENSORY INTERFACES: IMPROVED ALGORITHM FOR CONTROLLING DISTANCE IN 3-D AUDIO DISPLAYS*. MCLEAN, VA: PLANNING SYSTEMS, INC. (DTIC NO. ADB224426)

Abstract: The project goal was to produce an algorithm for synthesizing auditory distance which would be accurately perceived with little or no-learning required. The algorithm could be added to an existing Air Force 3-D audio system which uses head-phones in a noise-reducing helmet. The approach was to combine very accurate recently developed atmospheric modeling with head-related transfer functions (HRTFs) to produce realistic simulation of outdoor sound propagation. In Phase 1, 300-ms white-noise bursts were processed by the model to represent source-distances of 200, 400, 800, 1609, and 3200 meters. Listeners were asked to identify the distances. Results showed that the model provided more effective distance cues for 3-D sound than a simpler model. Commercial uses of the distance algorithm would include commercial aviation, as well as

training media and virtual reality games. This SBIR could be applicable to PSI's work on future Traffic Collision and Avoidance System concepts for the FAA (currently being performed under a subcontract to the MITRE Corporation).

GILKEY, R. H. (1998). *INSTRUMENTATION TO ENHANCE DOD-RELEVANT RESEARCH ON COGNITIVE WORKLOAD IN UAVS, IMAGE, EXPLOITATION, AND SPATIAL HEARING*. DAYTON, OH: WRIGHT STATE UNIVERSITY DEPT OF PSYCHOLOGY. (DTIC NO. ADA357190)

Abstract: The project goals have been to provide enhanced real-time graphics generation capacity, computational power, and real-time audio signal processing capability for the Virtual Environment Research, Interactive Technology, And Simulation (VERITAS) facility, making it better suited to the demands of DoD-relevant research projects on human performance in complex environments. VERITAS is owned by Wright State University, but housed at Wright-Patterson AFB. It includes a CAVE(Trademark), which is an immersive, wide field-of-view, stereoscopic, real-time interactive display system, allowing the user to move through virtual environments with minimal encumbrances. The CAVE(Trademark) is controlled by a Silicon Graphics Onyx(trademark) computer with InfiniteReality(Trademark) graphics. The high-fidelity simulations in this facility allow a variety of questions related to human effectiveness to be addressed. The DURIP funds were used to purchase three, high-performance computer subsystems: a multiprocessor computational subsystem, a graphics generation subsystem, and an acoustics generation subsystem. These subsystems provide critical capabilities for computationally intensive, real-time-constrained applications, including simulation, virtual environments, auditory and visual displays, motor control, and human perception and cognition. This instrumentation has supported specific funded DoD projects investigating: (1) display and control representations for UAV operation, and (2) binaural and spatial hearing.

GLUMM, M. M., BRANSCOME, T. A., PATTON, D. J., MULLINS, L. L., & BURTON, P. A. (1999). *THE EFFECTS OF AN AUDITORY VERSUS A VISUAL PRESENTATION OF INFORMATION ON SOLDIER*. ABERDEEN PROVING GROUND, MD: ARMY RESEARCH LAB. (DTIC NO. ADA368873)

Abstract: This report describes a field study designed to measure the effects of an auditory versus a visual presentation of position information on soldier performance of land navigation and target acquisition tasks. Measures of situational awareness, stress, cognitive performance, and workload were also obtained. In the auditory mode, position information was presented in verbal messages. In the visual mode, the same information was provided in text and graphic form on a map of the area of operation presented on a helmet-mounted display (HMD). During the study, 12 military volunteers navigated densely wooded unmarked paths that were 3 km long. Although no differences were found between the two display modes in the frequency at which navigational and other tactical information was accessed, the analysis of responses to probe questions indicated that participants maintained a greater awareness of position with respect to waypoints, targets, and other units when information was presented visually than when information was presented auditorily in verbal messages. In the auditory mode, as the participants' perceptions of time demands increased, post-test scores on a logical reasoning task tended to be higher than pre-test scores. Although visual presentation of information appeared to enhance position awareness, differences between the two display modes in navigation and target acquisition performance were not found to be statistically significant. The findings of the investigation suggest differences in cognitive processing requirements between the two displays and the impact of attentional focus and practice on cognitive performance.

HAAS, M. W., BEYER, S., DENNIS, L. B., BRICKMAN, B. J., & HETTINGER, L. J. (1997). *AN EVALUATION OF ADVANCED MULTISENSORY DISPLAY CONCEPTS FOR USE IN FUTURE TACTICAL AIRCRAFT*. DAYTON, OH: LOGICON TECHNICAL SERVICES, INC. (DTIC NO. ADA328767)

Abstract: Pilots from three NATO countries participated in simulated air combat scenarios in which they either flew a conventional cockpit, consisting of F-16/F-15 type cockpit displays, or a virtually-augmented cockpit, consisting of advanced head down/head up displays, helmet mounted displays/trackers, 3 dimensional auditory displays, and haptic displays. Pilots flew simulated air intercept missions against a four-ship ground attack group supported by two air to air adversary fighters. The pilot flying the principal cockpit was instructed to try to shoot down the ground-attack group and return to a pre-defined safe air space without being shot down by adversary aircraft. The degree to which pilot performance was differentially affected by the conventional versus virtually-augmented cockpit manipulation was assessed using objective and subjective measures including pilot-aircraft lethality/survivability, pilot workload, and pilot situation awareness. Results indicated a significant advantage for the virtually-augmented interface condition in the number of missions won, exchange ratio, mission length, and number of ground strikes. In addition, the performance improvements yielded by the virtually-augmented crew station were realized with enhanced situation awareness and a reduction in workload compared to the conventional crew station. Furthermore, post flight debrief questionnaires produced highly favorable subjective reports from pilots.

HALL, T. J., PASSEY, G. E., & MEIGHAN, T. W. (1965). *PERFORMANCE OF VIGILANCE AND MONITORING TASKS AS A FUNCTION OF WORKLOAD*. MARIETTA, GA: LOCKHEED-GEORGIA CO HUMAN FACTORS RESEARCH LAB. (DTIC NO. AD0615921)

Abstract: The study was conducted to obtain control data on the performance of three passive tasks--auditory vigilance, warning lights monitoring, and probability monitoring performed previously in conjunction with three active tasks. Subjects were tested for 4 hours on each of 6 successive days. A task schedule requiring performance of all six tasks was employed on 2 hours of each daily session, while performance on the passive tasks alone was carried out during the remaining 2 hours. Performance on auditory vigilance, green warning lights, and probability monitoring was found to be superior when these passive tasks were performed alone. No difference in performance was found for red warning lights.

HOEGEMAN, JR. H. F. RHEINLANDER, T. W., & RUMER, J. (1972). *DEVELOPMENT OF AN AIRBORNE DIGITAL MESSAGE ENTRY DEVICE*. WESTLAKE VILLAGE, CA: BUNKER-RAMO CORP ELECTRONIC SYSTEMS DIV. (DTIC NO. AD0893034)

Abstract: The first phase of this program involved a study to determine the design requirements for a digital message entry device (DMED) for use by pilots of light Air Force aircraft, and to formulate a concept capable of satisfying those requirements. The primary mission application considered was that of the airborne forward air controller and the composition of TADIL-D messages. The requirements of other missions and potential digital messages also were taken into account in determining the design requirements. Additional factors analyzed were: (1) the other concurrent activities of the DMED's pilot-user (an estimate was made of the workload on his mental and physical faculties), (2) the physical and anthropometric constraints of the cockpit environment, (3) the problems of integrating a DMED into such an environment and remaining mutually compatible with other avionics systems, (4) the major human engineering considerations concerning DMED's prompting and input mechanisms, (5) experimentation confirming the feasibility of using an auditory display (as well as the more conventional visual displays) as the prompting device, and (6) a survey of pertinent technological areas to identify

the possible hardware and techniques available to implement the DMED. On the basis of the preceding considerations, tradeoffs were performed to generate a set of concept requirements.

KARNEY, D. H. (1991). *ARMY AEROMEDICAL RESEARCH LABORATORY ANNUAL PROGRESS REPORT: CALENDAR YEAR 1990*. FORT RUCKER, AL: ARMY AEROMEDICAL RESEARCH LAB. (DTIC NO. ADB154400)

Abstract: The Annual Progress Report gives the CY 90 personnel and funding strength of the U.S. Army Aeromedical Research Laboratory. It outlines the 11 scientific programs being pursued by the Laboratory. These programs are: Visual and auditory physiology; auditory effects of blast overpressure; noise hazards of combat vehicles; impact biodynamics of crashworthy aviation equipment and personnel armor; vibration hazards of combat vehicles; crew life support systems technology; sensory limitations and man/machine systems; biomedical aspects of crew workload, selections, and staffing; anthropometry and ergonomics; criteria for Army aviators; and antidote and antidote/agent effects on the visual system.

KAUFMAN, L. & WILLIAMSON, S. J. (1986). *PERCEPTUAL FACTORS IN WORKLOAD: A NEUROMAGNETIC STUDY*. NEW YORK, NY: NEW YORK UNIVERSITY. (DTIC NO. ADA169934)

Abstract: A background section describes the neuromagnetic method and its history. There were an elevation of N1 and P2 (using a quasi-steady state stimulus). The fields associated with these sources increased in intensity during attention. This is not due to the activity of sources recruited during attention, but to Modulated activity of neurons in or near primary auditory cortex. This is consistent with a Triesman like filter theory of attention. Also, physical parameters of stimulation, e.g., loudness, have little or no effects. However, the effect is sharply diminished when both stimuli are presented to both ears with equal loudness. A collaboration with other investigators is planned to compare our results with results obtained in a more conventional manner. A new method for obtaining graded levels of attention is described. A visual experiment is underway, and is giving us similar results. A single-position method for determining the location, orientation and strength of the dipole source is described. This method will be applied to a P300 study, which will follow-up an odd-ball study just completed. The latter gave results similar to those obtained previously, but the method is sufficiently insensitive to determine if changing P300 latency is due to a change in source. The planned experiment should make this possible.

KAUFMAN, L. & WILLIAMSON, S. J. (1987). *PERCEPTUAL FACTORS IN WORKLOAD: A NEUROMAGNETIC STUDY*. NEW YORK, NY: NEW YORK UNIVERSITY. (DTIC NO. ADA179143)

Abstract: This annual report describes the five channel magnetometer operating at NYU, and the principles underlying its use. It further describes recent advances in methodology, including the results of a theoretical study showing that measurement of the field at least five different positions is needed to fully characterize a single dipole source. The number of recording positions increases markedly with noise. Therefore, a shielded environment would minimize the number of recording sessions required for a neuromagnetic study. The report also provides a history of the work in relevant areas, and goes on to describe a completed study of selective auditory attention. It was found that magnetic counterparts of N100 and P200 of the event related potential show a strong effect of attention in a dichotic listening task. The magnetic components (N100m and P200m) can be accounted for by sources located in the auditory cortex, and do not change in position or depth with attention. The effect of attention is to change the tangential current dipole moment. Analysis of variance (ANOVA) using the field measurements near field extrema show that the only effect of significance is that of the instruction to attend or not to

attend to the stimulus. This result is reflected in the change in source intensity (dipole moment). The results are consistent with an early filter theory of attention, and seem to be inconsistent with the analysis by synthesis approach. Moreover, the results suggest that the filtering operations associated with selective attention occur in the primary sensory projection areas, although roles for other areas cannot be completely ruled out.

KAUFMAN, L. & WILLIAMSON, S. J. (1988). *PERCEPTUAL FACTORS IN WORKLOAD: A NEUROMAGNETIC STUDY*. NEW YORK, NY: NEW YORK UNIVERSITY. (DTIC NO. ADA198487)

Abstract: This final report includes descriptions of substantive experimental studies of neural phenomena related to attention and auditory perception. It also describes efforts to enhance the superconducting instruments and other devices needed for the rapid and accurate accumulation of neuromagnetic data, and advances made in techniques for calibrating these instruments and for analyzing neuromagnetic data. The substantive experiments included a major study of the magnetic N100 phenomena and its sources and how they are affected by selective attention. Its relationship to the electrical N100 is considered, and required future research described. Also, work on the magnetic P300 phenomenon is described. This work confirmed earlier studies showing that the equivalent current dipole source is located in or near the hippocampal formation. The localization of multiple auditory sources is described. Improvements in instrumentation include the installation of a new gantry for purposes of evaluation, the design of a novel device for quantifying positions in magnetic resonance images, and the development of a graphics program for depicting a current dipole in the heads of subjects are also described. New methods for calibrating multisensor systems were developed, and the details are provided in the report. Finally, an opportunity arose during the course of this project to locate a very small metallic object accidentally embedded in the back of a human patient. This allowed us to obtain surgical verification of magnetic methods for locating sources. The predicted position was accurate within two millimeters.

KENNEDY, R. S., MAY, J. G., JONES, M. B., & FOWLKES, J. E. (1989). *DEVELOPMENT OF SACCADE LENGTH INDEX OF TASKLOAD FOR BIOCYBERNETIC APPLICATION*. ORLANDO, FL: ESSEX CORP. (DTIC NO. ADA205199)

Abstract: The idea which prompted the present research was that biological events may be predictive of the attentional and task demands of work. If these could be analyzed in real time and fed back to the machine (or operator), a truly biocybernetic system could be created. A nonintrusive reliable measure of individual differences such as attention during monitoring and control tasks has obvious biocybernetic relevance, particularly in dynamic environments and for design of equipment. Two investigations were performed to assess the feasibility of using specific characteristics of eye movement saccades as unobtrusive indicants of mental workload. Eye movements were measured while subjects were differentially task loaded by simple, moderate, and complex auditory tone counting. The results indicated that the extent of saccadic eye movements varied inversely in subjects as tone counting complexity increased. Saccade length; Mental workload; Human performance; Biocybernetics. (kt)

KOBUS, D. A. & LEWANDOWSKI, L. J. (1991). *CRITICAL FACTORS IN SONAR OPERATION: A SURVEY OF EXPERIENCED OPERATORS*. SAN DIEGO, CA: NAVAL HEALTH RESEARCH CENTER. (DTIC NO. ADA258924)

Abstract: A survey questionnaire was administered to 538 sonar operators (surface and submarine) of various rates and experience to investigate and document their perceptions of: (a) factors important to sonar operation, (b) job stressors, and (c) operational problems. Results indicated a high level of agreement among sonar operators across types of service and rate.

Primary factors rated as very important to sonar operation included: ability to stay alert, ability to integrate visual and auditory information, fatigue, work cycle factors, one's motivation to perform, quality of equipment, and amount of sea experience. The most commonly nominated stressors were fatigue, length of sea tour, length of watch, poor leadership, and collateral duties. Operational problems most frequently noted were poor leadership, lack of sleep, collateral duties, and visitors in sonar. Overall, the results suggest that greater consideration be given to issues of fatigue, workload, attention, the quality of supervision in sonar, and training that includes realism, teamwork, and increased classification efficiency.

KRAMER, A. F., WICKENS, C. D., & DONCHIN, E. (1983). *AN ANALYSIS OF THE PROCESSING REQUIREMENTS OF A COMPLEX PERCEPTUAL-MOTOR TASK.* CHAMPAIGN, IL: ILLINOIS UNIVERSITY PSYCHOPHYSIOLOGY LAB. (DTIC NO. ADA158715)

Abstract: Current concerns in the assessment of mental workload are discussed, and the event-related brain potential (ERP) is introduced as a promising mental-workload index. Subjects participated in a series of studies in which they were required to perform a target acquisition task while also covertly counting either auditory or visual probes. The effects of several task-difficulty manipulations on the P300 component of the ERP elicited by the counted stimulus probes were investigated. With sufficient practiced subjects the amplitude of the P300 was found to decrease with increases in task difficulty. The second experiment also provided evidence that the P300 is selectively sensitive to task-relevant attributes. A third experiment demonstrated a convergence in the amplitude of the P300s elicited in the simple and difficult versions of the tracking task. The amplitude of the P300 was also found to covary with the measures of tracking performance. The results of the series of three experiments illustrate the sensitivity of the P300 to the processing requirements of a complex target acquisition task.

LARKIN, R. J. (1983). *A COMPARISON OF AUDIO, VISUAL, AND TACTILE WARNING DEVICES IN A SIMULATED FLIGHT ENVIRONMENT.* MONTEREY, CA: NAVAL POSTGRADUATE SCHOOL. (DTIC NO. ADA128200)

Abstract: An experiment was performed in which fifteen subjects responded to three separate warning devices; an audio, visual, and tactile device. Reaction times to each randomly presented device were measured while each subject was simultaneously engaged in piloting a personal flight simulator. Instructions to the subjects were continually presented visually on a TV monitor and verbally through a set of earphones. The mean reaction times for each device were compared using a difference of means t-test. The results showed that the tactile device produced significantly faster reaction times at the alpha = .01 significance level. This led to the conclusion that a tactile warning device could be effective in a flight environment where visual and auditory senses can easily be.

LEHMAN, E. F. & JENKINS, M-L. (1990). *HANDBOOK FOR CONDUCTING PILOT-IN-THE-LOOP SIMULATION FOR CREW STATION EVALUATION*. DAYTON, OH: VEDA INC. (DTIC NO. ADB141991)

Abstract: The handbook was prepared under the Cockpit Automation Technology (CAT) advanced development project. Its objective is to provide guidance in the planning, conduct and analysis of pilot-in-the-loop (PIL) evaluations of crew station design. Its intended audience consists of test director and other personnel involved in planning for, managing, or evaluating PIL simulation programs. While the handbook defines a broad range of simulation, its primary emphasis is on full-scale cockpits set in large domes which surround the pilot with realistic visual, tactile and auditory cues. The handbook, and the CAT process, stress the use of simulation in ways which foster promising new automation concepts, promote sound engineering practices, and control costs. It includes guidance in staffing, scheduling, requirements definition, conduct, analysis, and reporting of test results. The appendices include a quick-reference checklist for conducting PIL simulation for crew station evaluation, and sample forms and questionnaires associated with those evaluations.

LINDHOLM, E. CHEATHAM, C., & BUCKLAND, G. (1981). *PHYSIOLOGICAL AND DUAL TASK ASSESSMENT OF WORKLOAD DURING TRACKING AND SIMULATED FLIGHT*. TEMPE, AZ: ARIZONA STATE UNIVERSITY DEPT OF PSYCHOLOGY. (DTIC NO. ADA119218)

Abstract: A visuomotor task of moderate complexity (tracking) and one of high complexity (simulated aircraft carrier landing) were performed alone, then in combination with a tone discrimination task at two levels of difficulty in usual dual task fashion. Measures of autonomic nervous system activation (heart rate, skin conductance) and central nervous system information processing (event related potentials) were quantified continuously during performance of all tasks. The dual task results were typical, given that most subjects treated the tone discrimination task as 'secondary' (low priority): tone discrimination performance degraded when the tone mask was combined with the tracking task and degraded even more when the tone task was combined with the carrier landing task. While dual task methodology adequately described gross changes in workload, the physiological data permitted much more detailed interpretations and descriptions of training effects (practice), tone mask information processing, individual differences, and visuomotor task control parameters than was possible by analysis of secondary task performance. It is concluded that the physiological method has distinct advantages over the dual task method, due mostly to the nonintrusive nature and the greater detail of results afforded by the former method.

LINDHOLM, E., CHEATHAM, C., KORIATH, J., & LONGRIDGE, T. M. (1984). *PHYSIOLOGICAL ASSESSMENT OF AIRCRAFT PILOT WORKLOAD IN SIMULATED LANDING AND SIMULATED HOSTILE THREAT ENVIRONMENTS*. TEMPE, AZ: ARIZONA STATE UNIVERSITY TEMPE DEPT OF PSYCHOLOGY. (DTIC NO. ADA140469)

Abstract: In two experiments, physiological metrics of cockpit workload were investigated in highly realistic flight simulators. In Experiment 1, non-pilot males were trained on a simulated landing task and a secondary, tone discrimination task while heart rate, skin conductance, and brain event-related potentials were continuously quantified. The results showed that heart rate was a more stable measure of workload than was skin conductance. Heart rate increased during each final approach to landing, and mean heart rate decreased as the subjects gained mastery over the task as a function of practice. Four ERP components (N1,P2,N2,P3) were statistically evaluated. As workload increased, N2 became more negative and P3 became less positive; also,

as workload increased, the latency difference between P3 and N1 increased. Finally, a within-subject regression analysis was employed to express the extent to which the four ERP components were intercorrelated. This measure proved to have considerable power to predict how well individual subjects would perform on the landing tasks. In Experiment 2, rated male pilots flew a simulated mission involving threat by surface-to-air missiles (SAMs). Heart rate, respiration activity, and ERPs were quantified by means of a custom-designed, miniaturized recording system. The pilots were informed of the level of SAM threat by tones sounded in the headset. The results showed that heart rate and respiration activity increased as SAM threat increased.

MACK, C. I. (1997). *USER REQUIREMENTS FOR AN OBSTACLE WARNING SYSTEM.*

DOWNSVIEW, ONTARIO: DEFENCE AND CIVIL INSTITUTE OF ENVIRONMENTAL MEDICINE. (DTIC NO. ADB229408)

Abstract: This paper presents a recommended way ahead for the interface design of Defence Research Establishment Valcartier's Eye-safe Laser-Based Obstacle Warning System. The paper reports the results of a literature review and a focus group meeting held at a tactical helicopter squadron. The review identifies several requirements for the integration of an effective obstacle warning system into a military helicopter environment. It is recommended that development of an auto-wire warning system with an audio display be undertaken, followed by an integrated obstacle avoidance and navigation display.

MAGER, G. L., JR (1974). *AN AUDIO DISPLAY OF PROCESSED ACOUSTIC SIGNALS.*

MASTER'S THESIS, MONTEREY, CA: NAVAL POSTGRADUATE SCHOOL. (DTIC NO. AD0783867)

Abstract: An audio display system using eight tones to encode the output of a digital signal processor is investigated. The purpose of the system is to detect and display an audio tone masked by bandlimited Gaussian noise. The digital processor performs a spectral analysis on the signal using a Fast Fourier Transform. Several hundred experiments were performed using a human listener to monitor the display. The experimental system is capable of displaying the difference between signal, no signal, and signal plus noise conditions. About 80% probability of correct decision by the human observer was achieved for input signals below the detection threshold for an unaided listener. Possible applications to a sonar system are indicated.

MALKIN, F. J. & CHRIST, K. A. (1985). *HUMAN FACTORS ENGINEERING ASSESSMENT OF VOICE TECHNOLOGY FOR THE LIGHT HELICOPTER FAMILY (LHX).* ABERDEEN PROVING GROUND, MD: HUMAN ENGINEERING LAB. (DTIC NO. ADB095952)

Abstract: This report was written in support of the technology trade-off analysis (TOA) performed for the Light Helicopter Family (LHX). The human factors aspects of applying voice technology to an LHX aircraft with full-scale development in 1987 are addressed. A description of voice technology and its advantages and disadvantages is provided, potential applications for voice technology in an LHX aircraft are discussed, the issues related to voice technology applications are reviewed, and conclusions are drawn. Concepts for the cockpit include a high level of automation which may enable the demanding tasks described above, which are currently performed by two crewmembers, to be performed by a single pilot. This automation would incorporate high-technology sensors and advanced displays and controls using artificial intelligence and voice technology. Voice technology is being considered for the LHX because it provides an alternative means of interacting with onboard systems. It is anticipated that the visual and manual workload of aircrews can be reduced somewhat by converting some of the visual and manual tasks to speech and auditory tasks.

MANAKER, E. (1982). PILOT ABILITY TO UNDERSTAND SYNTHETIC VOICE AND RADIO VOICE WHEN RECEIVED SIMULTANEOUSLY. BETHPAGE, NY: GRUMMAN AEROSPACE CORP. (DTIC NO. ADA119137)

Abstract: The goals of a prior study were to determine if synthetic voice messages would reduce the F-14 aircraft pilot's workload, increase his effectiveness during the mission, and to establish the hardware impact on the aircraft. Recommendations for additional studies to use voice in the F-14 and other future naval aircraft were made as well as for investigations into related areas such as crew perception and discrimination of a computer generated voice. The goals of a prior study were to determine if synthetic voice messages would reduce the F-14 aircraft pilot's workload, increase his effectiveness during the mission, and to establish the hardware impact on the aircraft. Recommendations for additional studies to use voice in the F-14 and other future naval aircraft were made as well as for investigations into related areas such as crew perception and discrimination of a computer generated voice. Some pertinent questions arising from the F-14 study concerned: the distinctiveness and intelligibility of a computer generated synthetic voice in the aircraft hearing situation; whether or not the pilot can separate radio-transmitted human voice messages of interest from simultaneously generated synthetic voice messages; and the optimum method of presenting such messages through the headset. An exploratory study was designed to investigate these questions. The intent was to examine differing methodologies in presenting the stimuli used, and to ascertain trends in the subjects performance data.

MARTIN, J. J. (1993). AIRBORNE DEMONSTRATION OF A 3-D AUDIO DISPLAY. CHINA LAKE, CA: NAVAL AIR WARFARE CENTER WEAPONS DIV. (DTIC NO. ADB175694)

Abstract: The Airborne 3-D Audio Display Demonstration Project integrated a 3-D cueing system into the back seat of a TAV-8B Harrier aircraft for flight demonstration and validation of the 3-D concept. The system was capable of providing direction-of-arrival audio to the aft pilot to assist in maintaining situational awareness and/or providing cues on the location of targets or navigation waypoints. 3-D audio was expected to reduce pilot workload by exploiting the natural human tendency or behavior to attend to localized audio cues in 3-D space. The demonstration also investigated the validity and effectiveness of separating multi-channel communication clutter via localized audio cues, as well as the effectiveness of active noise reduction for a high-noise-level cockpit environment. This was the first time a 3-D audio cueing system had ever been flown; therefore, the project was limited to demonstration, investigation, and validation of the system performance in a tactical aircraft environment.

MAY, J. G., KENNEDY, R. S., & FOWLKES, J. E. (1987). DEVELOPMENT OF SACCADE LENGTH INDEX OF TASKLOAD FOR BIOCYBERNETIC APPLICATION. ORLANDO, FL: ESSEX CORP. (DTIC NO. ADA189384)

Abstract: This report reviews progress made during the first year of a two year Phase II SBIR program to develop the Saccade Length Index of Mental Workload or SLIT. The ultimate goal of this effort is to develop a fully portable system to measure workload using the SLIT metric. Phase I work showed that workload and saccade length were related when workload was manipulated using an auditory tone counting task. Research conducted thus far in Phase II has replicated the Phase I results and has also shown 1) that the saccade length index is not affected by extended practice on a difficult tone counting task, and 2) that practice on a difficult tone counting task does not invalidate the saccade length measure when subjects perform less difficult levels of the same task. Preliminary results suggest that saccade length reflects workload on visual counting tasks in addition to auditory counting tasks, thus extending the possible application of SLIT to visual tasks which do not require precise visual fixation or tracking.

Hardware has been purchased for the SLIT system and progress has been made on software development so that SLIT system may be automated for data collection and analyses.

MAY, J. G., KENNEDY, R. S., WILLIAMS, M. C., DUNLAP, W. P., & BRANNAN, J. R. (1986). *EYE MOVEMENTS AS AN INDEX OF MENTAL WORKLOAD*. ORLANDO, FL: ESSEX CORP. (DTIC NO. ADA169941)

Abstract: Two investigations were carried out to assess the feasibility of using eye movement measures as nonintrusive indicants of mental workload. In the first experiment, measures of saccadic latency and eye movement velocity were obtained during alternating eye movement scans while subjects were differentially task loaded by simple, moderate, and complex auditory tone counting. The latency and eye movement velocity measures changed but did not differ reliably as tone counting complexity (workload) was increased. In the second experiment, the spatial extent of spontaneous saccades was measured under three levels of tone counting complexity. The results indicated that the extent of such eye movements varied inversely (p less than .0151) as tone counting complexity increased. This index appears to hold promise for the development of an objective indicator of mental workload.

MCLEAN, G. A., SMITH, L. T., HILL, T. J., & RUBENSTEIN, C. J. (1993). *PHYSIOLOGICAL CORRELATES OF STRESS-INDUCED DECREMENTS IN HUMAN PERCEPTUAL PERFORMANCE*. OKLAHOMA CITY, OK: OKLAHOMA UNIVERSITY HEALTH SCIENCES CENTER. (DTIC NO. ADA274240)

Abstract: Stress-induced changes in human performance have been thought to result from alterations in the 'multidimensional arousal state' of the individual, as indexed by alterations in the physiological and psychological mechanisms controlling performance. Identification of such changes in substrate activities provide more complete descriptions of both the performance changes and the arousal state/mechanisms. In this study, decrements in perceptual performance were produced by independent and combined administration of atropine, sleep loss and exercise for both a visual aircraft identification task and an auditory vigilance task; measurements of performance changes were accompanied by state measures of cardiovascular function, pupillary diameter, sleep onset latency, and subject self-reports. Observed performance changes were accompanied by monotonic increases in heart rate after atropine and exercise, but not sleep loss. Moderate exercise produced blood pressure changes indicative of physical workload, but only atropine increased diastolic blood pressure and pupillary diameter relative to performance effects. Atropine and sleep loss each reduced sleep onset times to less than 50 percent control values.

MEISTER, D. (1953). *SONAR CONTACT CLASSIFICATION. II. A STUDY OF CLASSIFICATION CUES REPORTED BY EXPERIENCED OPERATORS*. SAN DIEGO, CA: NAVY ELECTRONICS LAB. (DTIC NO. AD0015511)

Abstract: Thirty-one experienced sonarmen and ASW officers were given a questionnaire in which they described the frequency with which 28 target characteristics occurred in 6 types of sonar contacts: 3 submarine aspects and 3 types of nonsubmarine contacts. Differences in the frequencies of occurrence were evaluated to determine the level of significance at which these cues differentiated the 6 types of contacts. Significant agreement was reported on the audio and PPI scope-display characteristics; no significant agreement was noted for tactical range-recorder (TRR) target characteristics. Only the audio display and 2 of the possible audio characteristics, Doppler and echo quality, appeared to be used extensively for classification at sea. The target characteristics significantly differentiated the general categories of submarine and nonsubmarine only in the case of the audio display. The reports of the sonarmen were more indefinite and more

variable for nonsubmarine contacts. The audio display was considered the most useful source of information in classification, followed by the PPI, TRR, attack-plotter, dead-reckoning track.

MITCHELL, D. K. (2000). *MENTAL WORKLOAD AND ARL WORKLOAD MODELING TOOLS*. ABERDEEN PROVING GROUND, MD: ARMY RESEARCH LAB. (DTIC NO. ADA377300)

Abstract: The author of this report provides an overview of mental workload theory and mental workload measurement. She also describes the development, application, and validation of the mental workload modeling tools developed by the Human Research and Engineering Directorate of the U.S. Army Research Laboratory (ARL). These ARL tools, VACP (visual, auditory, cognitive, psychomotor) option in the improved performance research integration tool (IMPRINT) and WinCrew, can help the designers of military systems to assess the mental workload associated with different configurations of soldiers and equipment involved in the performance of a mission. System designers can conduct this assessment in the concept development phase of system design and reduce the need to build costly system mock-ups.

MULLINS, L. F. & LUKAS, J. H. (1987). *BRAIN POTENTIALS AND PERSONALITY: A NEW LOOK AT STRESS SUSCEPTIBILITY*. ABERDEEN PROVING GROUND, MD: HUMAN ENGINEERING LAB. (DTIC NO. ADA186931)

Abstract: Today's soldier is confronted with physiological and psychological hardships that can affect the soldier's ability to function effectively and appropriately. This is seen as a breakdown of performance when sustained stress exceeds the soldier's capacity to cope. This experiment investigates an underlying constitutional factor, involving the central nervous system, that plays a role in how excitable an individual will be during any stressful or arousing situation. Subjects listened to 1,000-Hz tone bursts ranging 40 to 85 dB sensation level (SL) in 5-dB steps in a block-randomized fashion. The brain's electrical response to the tones was averaged and collected online. The peak amplitudes were measured and the slope of the line of best fit between evoked potential amplitude and intensity was computed. Auditory augmenters have positive slopes, that is, as intensity increases so does the evoked potential amplitude. Reducers show the opposite effect. The brain potentials become smaller or reduce as intensity increases, producing a negative slope. In addition, each subject completed Zuckerman's Sensation Seeking Scale (SSS) and Vando's Reducer-Augmenter (R-A) Scale. The slope measure was significantly correlated with the experience seeking subscale of the SSS. The results indicate that auditory augmenters prefer and seek out novel and exciting experiences. And in conjunctions with previous human and animal research, the results also suggest that the augmenter may cope better with stress and high workloads.

NELSON, W. T., HETTINGER, L. J., CUNNINGHAM, J. A., BRICKMAN, B. J., & HASS, M. W. (1998). *EFFECT OF LOCALIZED AUDITORY INFORMATION ON VISUAL TARGET DETECTION PERFORMANCE USING A HELMET-MOUNTED DISPLAY*. DAYTON, OH: LOGICON TECHNICAL SERVICES, INC. (DTIC NO. ADA357787)

Abstract: An experiment was conducted to evaluate the effects of localized auditory information on visual target detection performance. Visual targets were presented on either a wide field-of-view dome display or a helmet-mounted display and were accompanied by either localized, nonlocalized, or no auditory information. The addition of localized auditory information resulted in significant increases in target detection performance and significant reductions in workload ratings as compared with conditions in which auditory information was either nonlocalized or absent. Qualitative and quantitative analyses of participants' head motions revealed that the addition of localized auditory information resulted in extremely efficient and consistent search strategies. Implications for the development and design of multisensory virtual environments are

discussed. Actual or potential applications of this research include the use of spatial auditory displays to augment visual information presented in helmet-mounted displays, thereby leading to increases in performance efficiency, reductions in physical and mental workload, and enhanced spatial awareness of objects in the.

NIJHUIS, H. B. (1993). *WORKLOAD IN AIR TRAFFIC CONTROL COMMUNICATION*. AMSTERDAM, THE NETHERLANDS: NATIONAL AEROSPACE LAB (DTIC NO. ADB187743)

Abstract: In an experiment the traditional mode of voice communication between air traffic controllers and pilots (a vocal and auditory task) was compared with a data-link mode (a visual and manual task). Eight subjects controlled air traffic, both via voice channels and via data-link in a laboratory simulation. Mental workload was assessed through performance, heart rate variability and subjective judgement. The results pointed in the direction of a higher mental workload in the data-link mode than in the voice communication mode. The difference in workload could be attributed to a redistribution of the required cognitive resources.

OATMAN, L. C. (1989). *THE ROLE OF ATTENTION IN INFORMATION PROCESSING IMPLICATIONS FOR THE DESIGN OF DISPLAYS*. ABERDEEN PROVING GROUND, MD: HUMAN ENGINEERING LAB. (DTIC NO. ADA219252)

Abstract: A principal goal in human factors engineering (HFE) is to develop a theoretical and empirical basis for matching the attentional mechanisms of the human operator with the appropriate information portrayed by the visual display. Since a display serves as an interface between the human operator and a dynamic system, its structure and composition are critical to the operator's performance. A display compatible with the human operator's attention mechanisms will improve performance by allowing faster, more accurate information processing, and will minimize mental work load. The system designer has to predict which attention mechanism an operator will use in a specific task situation. A very effective human-system interface will result if the designer succeeds in matching the displayed information with the appropriate attention mechanism.

PALMER, B., NASMAN, V. T., WILSON, G. F., & GUNDEL, A. (1992). *A BRAIN-EVOKED POTENTIAL STUDY OF TASK DIFFICULTY USING VERBAL MEMORY AND MENTAL ROTATION TASKS*. WRIGHT-PATTERSON AFB, OH: ARMSTRONG LAB. (DTIC NO. ADA263871)

Abstract: Different task processing requirements may produce different patterns of brain evoked potential (EP) variation with changes in task difficulty. We examined and compared EP changes associated with variable task difficulty in two dissimilar tasks: (1) the auditory Sternberg memory task, and (2) a visuo-spatial mental rotation task. EPs were submitted to source derivation and evaluated for changes related to increased central processing difficulty. Mid-latency EP amplitudes were differentially sensitive to changes in memory search (Sternberg) or perceptual complexity (mental rotation). The amplitude of a later endogenous component varied with task difficulty in both tasks, but demonstrated unique topographic distributions as well as unique pattern changes. These findings support the view that task difficulty effects on EPs are observable as changes to both mid-and long-latency components, but that these changes may differ with the processing requirements of different tasks.

POLSON, M., FRIEDMAN, A., & SHUCARD, D. W. (1983). *RESOURCE ALLOCATION IN CEREBRAL SPECIALIZATION*. BOULDER, CO: COLORADO UNIVERSITY AT BOULDER INSTITUTE OF COGNITIVE SCIENCE. (DTIC NO. ADA128733)

Abstract: The object of this research was to develop and test a theoretical framework of cerebral

specialization in which each hemisphere is viewed as an independent information processing system. This framework is a special case of a multiple resources model of information processing in which we tie the existence and number of resource pools to the anatomical structure of the brain. We used the well specified dual task methodology of the multiple resources approach to assess the model with behavioral measures. In addition, we employed electrophysiological measures of resource allocation to verify certain of the assumptions we made in testing the model. In this model any given set of tasks can overlay partially, completely, or not at all in terms of the resources required from a particular hemisphere.

ROBINSON, C. P. (1984). *A COMPARISON OF PICTORIAL AND SPEECH WARNING MESSAGES IN THE MODERN COCKPIT*. WRIGHT-PATTERSON AFB, OH: AIR FORCE INSTITUTE OF TECH. (DTIC NO. ADA151917)

Abstract: This thesis presents a current trend in cockpit design to incorporate synthesized speech to present secondary information to the pilot in an attempt to reduce mental workload, and to allow the pilot to keep his or her view out of the cockpit. Theories of multiple resource information processing support both of these reasons to use synthesized speech, but theories of stimulus-central processing-response (S-C-R) compatibility suggest the possibility that spatial information presented visually may have some distinct advantages over speech even though it uses the same input modality as the primary (flying) task. If the response is to be manual, then spatial information is more compatible. Twenty subjects participated in three dual-task experiments which compared tracking and emergency response performance when information was presented in the visual/spatial (pictorial) mode as opposed to the auditory/verbal (speech) mode. In all three experiments the pictorial mode elicited quicker response times, though in one experiment the pictorial mode also elicited more errors. Also, the pictorial subjects improved more with learning than did the speech subjects. While the subjects were not successful at protecting their primary task when they added the secondary task, there were no interactions between the task type and any other factor. These results indicate that more research concerning the spatial advantages of pictorial displays needs to be conducted before too many speech displays are incorporated into the cockpit.

ROSENBERG, L. B. (1992). *THE USE OF VIRTUAL FIXTURES AS PERCEPTUAL OVERLAYS TO ENHANCE OPERATOR PERFORMANCE IN REMOTE ENVIRONMENTS*. STANFORD, CA: STANFORD UNIVERSITY CENTER FOR DESIGN RESEARCH. (DTIC NO. ADA292450)

Abstract: This report introduces the notion of virtual fixtures for use in telepresence systems. Tools and fixtures in the real world(e.g., a ruler guiding a pencil) enhance human performance by guiding manual operations, providing localizing references, reducing mental workload, and increasing precision. Virtual fixtures are computer-generated percepts overlaid on top of the reflection of a remote workspace which can provide similar benefits. Because such perceptual overlays are virtual constructions they can be diverse in modality, abstract in form, and custom tailored to individual situations. This study investigates the potential of virtual fixtures by implementing simple combinations of haptic surfaces and auditory sensations as virtual perceptual aids in a standardized telemanipulation task. Subjects viewed the remote environment through a vision system while wearing an upper-body exoskeleton. Eight subjects controlled a slave robot arm to perform standard Fitts' law peg-insertion tasks with and without the aid of a variety of virtual fixtures. Fixtures composed of haptic and auditory perceptual overlays increased operator performance up to 70%. Simple fixtures devised from basic elements can be powerful perceptual aids; a workstation environment might be developed to allow a teleoperator to design and implement virtual fixtures interactively.

RUBINSTEIN, L. & RUDOV, M. H. (1967). *ANALYSIS AND EVALUATION OF TACTICAL PENETRATION AIDS PENVAL PROGRAM. MEMORANDUM REPORT ON EXPERIMENTAL INVESTIGATIONS OF HUMAN AUDITORY CAPACITIES FOR USE IN THE DESIGN OF AUDIO DISPLAYS*. BUFFALO, NY: CORNELL AERONAUTICAL LAB INC. (DTIC NO. AD0819944)

Abstract: This report describes an experimental program aimed at arriving at some recommendations for transforming radar signals into auditory displays which are compatible with operator capabilities. Four experiments were conducted for the purpose of: (1) determining the feasibility of using the perception of the direction of a binaurally produced sound image as an audio display; (2) measuring the human capacity for judging the intermittency of audio signals; (3) examining the feasibility of using an auditory illusion of intensity change as a display; and (4) examining the interaction among signal dimensions.

SCARBOROUGH, E. L. (1992). *ENHANCEMENT OF AUDIO LOCALIZATION CUE SYNTHESIS BY ADDING ENVIRONMENTAL AND VISUAL CUES*. MASTER'S THESIS, WRIGHT-PATTERSON AFB, OH: AIR FORCE INSTITUTE OF TECH SCHOOL OF ENGINEERING. (DTIC NO. ADA259041)

Abstract: An audio localization cue synthesizer, the DIRectional Audio Display (DIRAD) was used to simulate auditory distance, room reflections, and to provide spatial audio for computer graphics images. The DIRAD processes input audio signals to generate spatially located sounds for headphone listening. The DIRAD can position audio sources around the head and these sounds are stable with respect to the listener's head position. An interactive, real-time simulation of auditory distance and room reflections was accomplished using the DIRAD in combination with a Silicon Graphics audio processor board installed in a Personal Iris 4D/35. Several demonstrations of auditory distance and the effects of early reflections are detailed, including a simulation of a direct sound source and three reflections that employed two DIRAD systems. Stored sound files were used to accompany three dimensional graphics images that were displayed on both a Silicon Graphics CRT and a three dimensional optical display device. The use of the 4D/35 audio processor board proved to be an effective means of preprocessing audio for the DIRAD for these simulations. The combination of AFIT's Silicon Graphics workstations and the DIRAD proved to be a practical solution to the problem of combining virtual visual and audio cues.

SEE, J. E. & VIDULICH M. A. (1997). *COMPUTER MODELING OF OPERATOR MENTAL WORKLOAD DURING TARGET ACQUISITION: AN ASSESSMENT OF PREDICTIVE VALIDITY*. DAYTON, OH: LOGICON, INC. (DTIC NO. ADA328970)

Abstract: The predictive validity of computer simulation modeling of the operator's mental workload and situational awareness (SA) during a target acquisition mission was assessed in the present study. In Phase 1, twelve participants completed a series of target acquisition trials in a laboratory flight simulator and provided subjective ratings of workload (using the Subjective Workload Assessment Technique (SWAT) and SA (using the Situational Awareness Rating Technique (SART)). In Phase 2 computer models of the laboratory task were constructed using the Micro Saint modeling tool. The visual, auditory, kinesthetic, cognitive, and psychomotor components of the workload associated with each task were estimated and used to obtain the measures of average and peak workload. The results from the lab data versus the Micro Saint data were similar but not identical, indicating the computer models were partially, but not completely valid predictors of mental workload and SA. The computer modeling appeared to be a more effective predictor of SA rather than mental workload.

STANNY, R. R. & SHULL, R. N. (1992). *EFFECTS OF TRANSDERMAL SCOPOLAMINE ON AUDITORY-MONITORING PERFORMANCE AND EVENT-RELATED POTENTIALS*. PENSACOLA, FL: NAVAL AEROSPACE MEDICAL RESEARCH LAB. (DTIC NO. ADA275866)

Abstract: Patch-administered, transdermal scopolamine is sometimes used to reduce the symptoms of motion sickness in aviators. The drug's side effects on attention and memory, however, have led to concern that the drug might compromise the abilities of those it was meant to help. The study described here examined the effects of transdermal scopolamine on performance and event-related potentials (ERPs) in an auditory-monitoring task. The scopolamine treatment yielded a small reduction in the discriminability of acoustic targets. Reaction times did not change significantly. Effects of the treatment were noticeable in concurrently recorded ERPs within 300 ms of the onsets of acoustic stimuli. The data were consistent with previous studies indicating that scopolamine affects attentional processes. The present results suggest that scopolamine's effects may be expressed quite early in the course of perceptual processing. Although the effects observed here were small, the drug nonetheless should be prescribed with caution, particularly in high-workload situations in which minor failures of attention could substantially increase probabilities of operator error.

TEAS, D. C. (1994). *THE DEVELOPMENT OF AUDITORY ICONS FOR REPRESENTATION OF VIRTUAL OBJECTS IN 3-D SPACE*. AUSTIN, TX: DYNASTAT, INC. (DTIC NO. ADA364329)

Abstract: Recent technology has enabled directional audio displays to be fielded in the cockpit. Directional audio displays convey the location of a sound source to the pilot. If a sound is chosen to indicate a certain event, qualitative data can also be communicated. This study examined several types of auditory signals, or icons, for use in the cockpit. Each of five icons was evaluated for five subjects' ability to localize and identify the icon. Spectral and temporal characteristics were varied among the icons. Three elevations were used for each of seven azimuth locations. Identification was nearly perfect for all icons while localization accuracy was highly variable. Both spectral and temporal features proved to be important for localization accuracy. Differences between subjects in elevation accuracy may be reduced by using custom head related transfer functions. These findings are directly applicable to the design of auditory icons for use in directional auditory displays to be fielded in the near future.

VIDULICH, M. & WICKENS, C. D. (1981). *TIME-SHARING MANUAL CONTROL AND MEMORY SEARCH: THE JOINT EFFECTS OF INPUT AND OUTPUT MODALITY COMPETITION, PRIORITIES AND CONTROL ORDER*. URBANA, IL: ILLINOIS UNIVERSITY AT URBANA ENGINEERING-PSYCHOLOGY RESEARCH LAB. (DTIC NO. ADA108721)

Abstract: This report addresses some of the issues that must be considered as voice recognition and synthesis (VRAS) technology is integrated into complex man-machine system environments. These issues include the input and output channels demanded by competing activities, task difficulty or workload, the allocation of attention and the nature of the task that - spatial or verbal - will be interfaced with VRAS. The present experiment addresses primarily the first three issues within the framework of multiple resource theory. Ten subjects performed first and second order tracking tasks either alone or concurrently with a Sternberg Memory Search Task with a set size of three letters. In different conditions the memory search task was presented either auditorily (A) or visually (V), and responses were executed with either a speech response (S), or manually (M). These generated four input/output combinations: AS, VS, AM, VM, that could be defined in terms of an increasing degree of resource overlap with the VM tracking task.

VOORHEES, J. W., MARCHIONDA, K. M., & ATCHISON, V. L. (1982). *SPEECH COMMAND AUDITORY DISPLAY SYSTEM (SCADS)*. MOFFETT FIELD, CA: ARMY RESEARCH AND TECHNOLOGY LABS AEROMECHANICS. (DTIC NO. ADA117486)

Abstract: The missions of the helicopter, within both the military and the civil sector, have changed rather dramatically over the last 20 years. The military's experience is Southeast Asia during the 1960's demonstrated the wide range of missions that could be accomplished by rotary wing aircraft: fire fighting, heavy lift, and large scale medical evacuations, as well as tactical missions of troop transport and close air support. The post-Vietnam civilian uses for helicopters have duplicated several of the military missions, resulting in an added interest in helicopters in both the military and the civilian sectors. This increased interest has also led to rapid advances in rotorcraft technology. As helicopters have become much more capable, there has been an increasing sophistication in flight controls, power plant systems, and in cockpit displays. This combination of the increase of types of missions and the increase in cockpit sophistication has created a new set of problems. The limiting factor for many types of helicopter missions is now the pilot; and the limitation appears to be specifically related to information transfer. This information transfer is in the form of aircraft status information to the pilot, and information transfer from the pilot back to the aircraft in the form of control manipulations.

WASHBURN, J. M. (1995). *IMPROVING THE MORSE INTERCEPT OPERATOR'S AUDIO DISPLAY*. MASTER'S THESIS, WRIGHT-PATTERSON AFB, OH: AIR FORCE INSTITUTE OF TECH. (DTIC NO. ADA305780)

Abstract: This thesis improves the audio display for multiple Morse communications. Factors considered to improve the audio display are frequency of source, volume level of source, and methods of unmasking. The best frequency and volume level of a Morse source is 500 Hz at 70 dB sound pressure level (spi). Two types of masking are researched: frequency masking and expectation driven masking. Experiments showed by amplifying high pitched sources the effects of frequency masking are minimized. Other methods to compensate for frequency masking are 3-D sound and the placement of a source out of phase between the ears. Morse code recognition at 500 Hz is greatest when presented at the NO Sr condition. Greatest unmasking for broadband signals occurs at 3-D locations (between 600 and 900) where the largest ITD (interaural time difference) exists. This thesis theorizes and confirms that greatest unmasking of a source tone in 3-D sound corresponds to the spatial location that gives an ITD equal to a 1800 phase shift for that tone. NASA/Ames Research Center has demonstrated that 3-D sound improves the performance of communication personnel who are required to monitor multiple speech communications. This thesis supports that result and further provides 3-D cues for simultaneous Morse sources. Research focuses on improving accuracy and reducing fatigue rather than increasing intelligibility. Fatigue is measured by subjects choice of which presentation option is easier to copy. The criteria for improving cues are minimal fatigue and the highest copy accuracy. The presentation options are 2-channel diotic (all sources in each ear), monaural (each channel contains a unique source, information of a source is presented to only one ear), 3-D angles of 0 deg, 10 deg, 32 deg, 45 deg, 58 deg, 69 deg, and 82 deg.

WEWERINKE, P. H. (1976). *HUMAN MONITORING AND CONTROL BEHAVIOUR. MODELS AND EXPERIMENTS*. AMSTERDAM, THE NETHERLANDS: NATIONAL AEROSPACE LAB. (DTIC NO. ADB025917)

Abstract: This report deals with a theoretical and experimental program concerning human monitoring and control behaviour. A model for multivariable monitoring (an automatic approach) was tested against experimental data. Apart from monitoring, simultaneously monitoring and manual flight director control was studied to determine the interference between (interacting) subtasks. Also combined monitoring and auditory tracking was included. The

results demonstrate that the multivariable monitor model adequately describes human monitor behaviour in the aforementioned tasks. Furthermore, a multivariable workload model has been developed. Computed workload has been shown to agree excellently with subjective ratings.